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EVOLUTION AND EPITOMIZATION.

I.

THE most significant characteristic of the sciences at the present time is the extent to which materialistic and mechanistic theories are elaborated and accepted. In saying this one need not ignore the situation in biology, where vitalism still exhibits some vigor; for it will be strange, after all, if the science of biology does not in its own development exhibit one of those mutations of which it speaks, and one of these days, with apparent suddenness, burst forth into a form which will at last give expression to its many latent and recessive mechanistic factors.

It is a problem for philosophy, concerned with the maintenance and development of abiding values, to know how to deal adequately with this trend of the sciences. In the past, it has been possible to depend upon a supposed duality of matter and spirit; but since the conception of spirit, especially in its teleological forms, is beset by difficulties, and since, according to the modern scientific view, no one can think of matter as threatening to prove ultimate, nor as being coarse, nor inert, nor degraded, one is led to suspect that men who never understood either matter or spirit jumped to the conclusion that they were opposites. Sometimes the views of Lotze and his successors are invoked to refute mechanism; but the day has gone by when anything which is admitted to be universal in extent can be dismissed as negligible in importance. Nowadays mechanism secretes its forces in the wooden horse of psychology, and thereby penetrates the very citadel and sanctuary of values. Of course a concrete value, an actual experience of valuation, is different from an abstract theory about a value; but to fix a gulf between the two, and to declare the latter incapable of interpreting the former, means the appearance of still more troublesome questions about the status of one, or the other, or both. Is it not time that a philosophy which still recognizes the importance of the problem of a sanction for our great values should, instead of trying to undermine materialism and mechanism, or get round them, accept them and try out their constructive possibilities? Perhaps the presence of values and ideas in the midst of a mechanistic world process can be accounted for in a way which will give them added significance by reason of their essential relations to it.

In this paper an attempt will be made to indicate, in a preliminary and sometimes tentative way, some of the steps in the development of such a view. It is obvious that such a view must call for a correlation of the sciences. The correlations usually attempted are either abstract and general, or else fragmentary, or else dependent upon what seems to be an inadequate epistemology. The great example of an abstract and general correlation is the theory of evolution. Fragmentary correlations are found in such combinations as physical chemistry and physiological psychology. A correlation pivoting upon epistemology is attempted when it is said that the various sciences are so many abstractions in which the universe is studied from different points of view.

Of these correlations the most striking is that afforded by the general theory of evolution. Two broad criticisms may be brought against it. From the side of pluralism it may be said that perhaps, even when formulated most scientifically, the theory imparts a false simplicity to the world—the evolutionary process may be only one current in the vast ocean of the universe. Another criticism comes from the side of philosophy of religion. If it be granted that philosophy of religion has a right to criticize in such matters, is it not significant that this most meaningful portion of philosophy has, after all, gained but little from this most prevalent and important of scientific concepts? From the questions suggested by Huxley's *Evolution and Ethics* to the attempts like that of Royce[1] to give evolution a ground in the Absolute, there seems to run a common motivation, to the effect that the theory of evolution, in one way or another, fails to measure up to the hopes or demands of religion. Only pragmatism and its kindred philosophies seem to hail the theory of evolution with anything resembling joy; and yet pragmatism, with all the data of evolution at its disposal, offers us adventure rather than assurance—forgetting that a process before which the doors of the future stand wide open can destroy its own treasures and devour its own children. There seems to be a need for the development of some line of thinking which, while agreeing with pluralism that we can at most analyze only a portion of the universe, and with pragmatism that absolute assurance is not possible, will, as against pluralism, treat the portion available for study as an organic whole, and, as against pragmatism, make clear, if possible, that there are certain principles which govern the process of evolution and prevent its wandering entirely afield.

The fragmentary correlations, noted above, are too familiar to need comment. The attempts to correlate the sciences by considering them as so many abstractions, so many partial views of the world process, taken from various angles and in accordance with different interests, bear witness to the basic fact that sciences do not develop without scientists, but fail after all to give due recognition to the overwhelming aspect of the universe, and to what we must suppose are the independent relations of its structures and processes. The vicissitudes of idealism ought to make it clear, if anything can, that the world is not a case of the knowing process, but that the knowing process is one of the interactions between some of the many structures—material, physiological and psychical—of which the world is composed.

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[1] *Cf.* J. Royce, *The Religious Aspect of Philosophy* (1885), pp. 238 ff, 460 ff.

Our proposition is, to study these structures and processes in detail, and thereby, while showing the partial nature of all the foregoing correlations of the sciences, to offer a basis for a new correlation. We shall include the knowing process, but regard it as a particular case of a wider group of interactions; and we shall use the data of evolution, but try to show that the process of evolution itself acquires new content and meaning when the data are exhibited as evidences of another process or group of processes which we call epitomizations.

Epitomization has three specific implications which we shall formulate in this paper. It may be defined in general as the occurrence, at the so-called later stages of evolution, of structures and processes which are essentially analogous to those occurring at the so-called earlier stages. Examples may be noted in the resemblances of atoms—if Rutherford's theories are to be accepted—and the solar system; or, of unicellular and multicellular organisms; or, according to some geologists, of an organism and the earth. By formulating the general definition as above, one avoids the question, unimportant for our purposes, whether the so-called earlier and later stages of evolution are correctly arranged, or whether, if a large enough portion of the universe is taken into consideration, all the structures and processes do not develop simultaneously. What is proposed is not so much a critique of the notion of evolution as a new analysis of the evidence which is cited as a basis of the theory of evolution. The use of the words "essentially analogous," and the method which they imply, can best be defended after some of the data have been examined.

II.

The first of the three implications of the hypothesis of epitomization leads to a kind of realistic monadism. It is the most abstract of the three, although not altogether separable from the other two. It involves more intricate and detailed work than the others, and offers some of the chief difficulties in the way of the development of the general argument. It is not pretended that the investigations here are complete, nor at some points beyond the hypothetical stage; but it is suggested that here is a line of inquiry which, even at the cost of much correction and reformulation, may be expected to remain significant. It is granted that such a monadism can show only one, or at most only a few of the factors which are operative in the world; but it is urged that to disregard this monadism is to disregard the details of the world's structures and processes. It ought to be noted that we are dealing not, as in the case of the older monadisms, with purely speculative entities, but with things which are studied in laboratories and observatories.

The theory of evolution assumes that certain of the constituents of the world as we now know it correspond to, if they do not survive from, other constituents at earlier stages of its development, and that these stages can be arranged in one or more evolutionary series. For example, when it is found that material bodies as we know them are made up of atoms or electrons, it is inferred that independently existing atoms or electrons have, at earlier stages of evolution, antedated those material bodies. Let us call each such quasi-independent constituent of the world a monad, taking the term in a sense neither less nor more definite than the term "individual"; and, without at present attempting to go far into the metaphysics involved, let us enumerate these monads as a step preliminary to that of indicating a schematic arrangement to which their analogous structures and processes can be reduced.

Beginnings in this case must be determined by the limitations of present-day scientific investigation. Without endeavoring to account for the origin of electrons, we may begin with (1) electrons in an electromagnetic field, where changes of velocity give rise to radiations. After these we may place the more or less familiar series—(2) atoms; (3) molecules; (4) masses of matter, including both the smaller and larger astronomical bodies; (5) our solar system and perhaps other solar systems; (6) larger units, more or less indeterminate, such as globular clusters,[2] our galaxy,[3] possibly some of the spiral nebulate,[4] and perhaps even one or more vast groups of spiral nebulae.[5] Bearing in mind that this is only a preliminary enumeration, and postponing many questions which arise concerning the relations of these monads, let us pass to another series, at least partially dependent upon the former. Here again it is hard to tell where the series begins, and any serial numbering of the monads must be open to question; but we may assume that some of the organic compounds of carbon are sufficiently distinguishable among chemical compounds, and sufficiently important in later developments, for us to consider them as monads. We may call these monads by the general term (..7?) "organic compounds." It is not difficult to find biologists willing to entertain, and even to develop somewhat, the assumption that some infra-cellular free living forms preceded the cells which we know;[6] but there is great diversity of terminology, and it is not clear what portions of the highly differentiated cells now known to us, if indeed any portions, may be supposed to correspond to the primitive free living forms. If persistence and definiteness of behavior of parts in the highly differentiated cells may be taken as indications of correspondence to certain free living primitive forms, some of these primitive forms may have been of the nature of microsomes[7] or chromatin granules;[8] but these subordinate units of the cells are themselves so complex from the point of view of organic chemistry[9] that it is hardly likely that the primitive forms which correspond to them represent merely the first stage of the synthesis of living matter. It seems better to regard them tentatively as (8 ?) later products, perhaps enzymic,[10] and quite likely corresponding to the chromatin of highly developed cells. Since in these cells both the genes[11] and the chromosomes[12] in which they are found are fairly well defined, it is quite possible that the term chromatin may include units of more than one degree of complexity.[13] The next two members of the series—(9 ?) unicellular organisms and (10 ?) multicellular organisms are evidently monads, within the meaning of the term. To think of the next member means to consider again the organismic theories of society;[14] but it accords with our procedure to suppose that the next member, or more likely the several members which should next be considered, are (11 ?..) social groups of multicellular organisms—plants and animals—and symbiotic populations[15] of various degrees of complexity.

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[2] H. Shapley, "Star Clusters and the Structure of the Universe," II, *Scientia*, 26; 355 (1919).

[3] *Ibid.*, III, *Scientia*, 27; 100 (1919).

[4] A. C. D. Crommelin, "Are the Spiral Nebulae External Galaxies?" *Scientia*, 21; 365 ff. (1917).

[5] *Cf.* A. S. Eddington, art. "Nebula," *Encyc. Brit.* (11), Vol. 19, p. 333.

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[6] E. B. Wilson, *The Cell in Development and Inheritance* (1896), pp. 21-22, and note.

[7] E. B. Wilson, *op. cit.*, p. 237.

[8] E. A. Minchin, "The Evolution of the Cell," in *Report of the British Association for the Advancement of Science*, 1915, pp. 437 ff.

[9] *Cf.* E. B. Wilson, *op. cit.*, p. 240.

[10] L. T. Troland, "The Chemical Origin and Regulation of Life," *Monist*, 24; 92 ff (1914) ; "Biological Enigmas and the Theory of Enzyme Action," *American Naturalist*, 51; 321 (1917).

[11] See T. H. Morgan, *The Physical Basis of Heredity* (1919), pp. 244-246.

[12] T. H. Morgan, "*The Mechanism of Mendelian Heredity* (1915), pp. 118 ff.

[13] *Cf.* Carl Snyder, "Life Without Oxygen," *Science Progress*, 6 (I) ; 134 (1911).

[14] For a survey of these theories see F. W. Coker, "Organismic Theories of the State, in "*Columbia University Studies in History, Economics and Public Law*, Vol. 38 (1910).

There remain some other entities which are not altogether different from some of the foregoing, and which are partially dependent upon them; these are best known to us in the nervous system. We are again confronted by difficulties in choosing the first members of the new series, but we may take them to be (..12?..) certain cells or groups of cells which become highly sensitive and specialized as effectors or receptors.[16] Along with these, and in combination with them, there appear in the course of development the nerve-cells and nerve-nets[17] which, together with their appropriate receptors and effectors, we shall call (13 ?) "nervous areas"—to consider the nerve-cells apart from their effectors and receptors is to reflect the procedure of the laboratory, not the course of evolution. As the next member of the series we take, for reasons which will be discussed below (14 ?), "simple,"[18] or "isolated"[19] reflex arcs, together with their appropriate receptors and effectors. Many of our nervous reactions are (15 ?) "complex reflexes," with appropriate receptors and effectors. All these enter into, or are differentiated within (16?..) the great complexes which constitute our emotional[20] and instinctive reactions, or—by the help of purposive ideas—our sentiments,[21] values, and "selves."[22]

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[15] A. J. Herbertson, "Discussion on Natural Regions of the World," in *Report of the British Association for the Advancement of Science, 1913*, p. 557.

[16] G. T. Ladd and R. S. Woodworth, *Elements of Physiological Psychology* (1911), pp. 16-17.

[17] *Ibid.*, pp. 17-18.

[18] C. S. Sherrington, *The Integrative Action of the Nervous System* (1906), p. 8.

[19] Ladd and Woodworth, *op. cit.*, p. 146.

[20] A. F. Shand, *The Foundations of Character* (1914), Chapter III.

The first implication of the hypothesis of epitomization is that if the series above enumerated be taken to represent even roughly the course of evolution, each monad, which marks a stage of evolution, exhibits structures and processes essentially analogous to those of the other monads. The course of evolution thus exhibits a series of epitomizations, in the first or monadistic sense of the term. That these characteristic structures and processes, which we shall now attempt to indicate, may recall sometimes the illustrations of Spencer's *First Principles* or the *a priori* methods of Hegel's *Naturphilosophie*, or numerous other relics of the past, is admitted, but held to be beside the point, which is whether the monads as defined exhibit the structures and processes or not.

Formulated briefly, the significant structures and processes may be said to be four—(I) *Individuation,* (II) *Interaction,* (III) *Reproduction,* (IV) *Integration.* Formulated in more detail, they include various subdivisions, as below. It may be noted that, although no hard and fast distinction is made, structures are emphasized in (I) and (IV), and processes in (II) and (III). Stated in more detail, the monadic formula is as follows:

> (1) *Individuation* of a monad, in (I-a) a milieu, which may include[23] [(I-a′) monads of stages previously developed, and] (I-a″) other independently arising monads of the given stage. This individuation is at most only relative, because of (II) *Interactions* of each monad with (II-a) the milieu [and (II-a′) monads of stages previously developed] and (II-a″) other monads of the same stage. With the inter-

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[21] *Ibid.*, Chapter IV.

[22] W. B. Pillsbury, *The Essentials of Psychology* (1914), p. 352.

[23] Portions of the formula enclosed in brackets indicate structures and processes which appear at later stages of evolution rather than at earlier; if they occur at earlier stages they have not been detected.

actions are associated processes of (II-b) accretion or depletion [and (II-b′) internal, compensating interactions] sometimes involving (II-c) attraction or repulsion, which (II-c′) varies as new interactions ensue; [the result may be (II-d) disintegration of the monad, but sometimes, before this occurs, (III) *Reproduction* of another monad or monads from it] with (III-a) differences between monads which—especially after some of these monads of any stage, say *n*, have formed monads of stage $(n+1)$, as in (IV-b), below—may be summed up as relative differences between the terms of (III-b) a duality. [Some of these dualities may come to affect the processes of (III-b′) reproduction in a complex way.] Several of these individual monads may form (IV-a) *Aggregates,* within which they are (IV-a′) juxtaposed in space, or (IV-a″) succeed one another in time; or, several of the monads—sometimes those already within aggregates—may form (IV-b) *Integrates.* In both aggregates and integrates each constituent monad modifies all its structures and processes by reason of the presence of the other constituent monads; that is, both aggregates and integrates are marked to some degree by (IV-b′) interrelations of parts and (IV-b″) differentiations of structure. The integrates (IV-b) of any given stage of evolution, *n,* differ from the aggregates (IV-a) of that stage, in that in the integrates the modifications of the constituent monads are more marked, and in that the integrates (IV-b) of any stage *n* are the individuated monads (I) of the stage $(n+1)$.

Any monads of a stage *n* which are not thus integrated may appear, in connection with a stage $(n+1)$, as (I-a′) monads of stages previously developed. The interrelations of parts (IV-b′) and differentiations of structure (IV-b″) of stage n are correlated, in the stage $(n+1)$, with the interactions (II) and reproductions (III), so that differentiations of structure (IV-b″) of the stage n appear in the stage $(n+1)$ as specializations of function.

[Sometimes new monads of the stage $(n+1)$ seem to arise not so much as the result of integrations (IV-b) of monads of the stage n, above described, but as the result of differentiations (IV-b″) of monads of some other stage, perhaps $(n+2)$. The fact seems to be that both processes are involved—that at some stages of evolution there is no integration of monads without concomitant differentiations of monads of other stages—and that in some cases of the production of new monads, the former process has (IV-c) been somewhat obscured by the latter.]

Before exhibiting the data for this monadistic scheme in such detail as will be possible within the limits of this paper, it may be noted that the scheme, although doubtless abstract enough, may, if taken as a description of the world, supply a metaphysics more concrete than that which deals with space, time, matter, motion, energy, cause, substance, and such concepts. The relations between this metaphysics and the other may be indicated by saying that the notion of substance arises when the milieu and its structures are conceived as uniformly as possible and that the other concepts noted arise when the interactions of various monads in the milieu are considered in one or another of their aspects at the expense of the rest. With a caution against carrying a comparison to detail before a more complete account has been finished, it may be noted that in the above formulation Process II has resemblances to Professor Sheldon's "productive quality,"[24] and Process

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[24] W. M. Sheldon, *Strife of Systems and Productive Duality* (1918), Chapters XII and XIII.

IV to Professor Spaulding's "creative synthesis;"[25] and that a way is thus offered in which two principles prominent in contemporary metaphysics may be viewed within a consistent whole.

III.

Coming now to some of the details of the data, let us consider (1) electrons.[26] As was indicated above, they mark the limits of our present knowledge of those earlier stages of evolution through which the universe, or a significant portion of it, may be said to have passed. Nothing is known concerning the evolution of electrons from any previous stage, although there have been many conjectures. In any attempted description of electronic structures or processes the limits of knowledge are very evident. Since the electron is not material, many characteristic resemblances comparatively easy to detect in the cases of other monads must be modified if not given up. Results attained by means of mathematical formulae are often difficult to state in terms of a mechanical model; but there is general agreement that at least any electron may be said to exist in a medium (I-a)—whether the medium is spoken of as aether, or space, or by some other term.[27] The medium is to be regarded as containing a vast number of electrons (I-a″)—there is no indication at present that one electron gives rise to another. That electrons interact (II) with their medium (II-a) is assumed in theories which account for radiations as due to electronic accelerations, and regard radiant energy as motion of a medium.[28] Electrons interact with other electrons (II-a″). They do not grow, as a material body may be said to grow, and their charges, so far as is known, remain constant; but it may be said that with their interactions are associated certain accretions and depletions (II-b), in the sense that their velocities, energies, and sometimes their masses[29] may increase or decrease. The interactions of electrons with other electrons are marked by attractions and repulsions (II-c), which depend upon relative positions (II-c′). Each electron differs from every other, even if the difference be only one of position in space and time (III-a). In the atomic relationships of electrons, there is a duality of positive and negative charges (III-b). The fact that the medium must be regarded as containing a vast number of electrons is another way of saying that electrons may be associated as an aggregate (IV-a). They may also, according to accepted theories, be integrated with positive nuclei—the exact nature of which is at present a matter of debate—into atoms (IV-b), marked by interrelations of parts (IV-b′) and differentiations of structure (IV-b″); the chief differentiation is that into central and peripheral regions. These atoms form the individuated monads (I) of the next stage (2), the structures and processes of which are considered in the next paragraph. It should be noted that, according to the recent work of Rutherford,[30] there is much to be said for the view that the heavier atoms are not built up directly from electrons, but from atoms of hydrogen and helium; the monadic formula has a place for such a process, below.

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[25] E. G. Spaulding, *The New Rationalism* (1918), pp. 448, 500.

[26] In this section the monads as enumerated above, are referred to by the Arabic numerals there tentatively assigned them; their structures and processes are referred to by the Roman numerals, with letters to indicate subdivisions, as found in the monadic formula.

[27] A. S. Eddington, letter in *Nature*, 107, 201 (1921).

[28] *Cf.* H. A. Lorentz, *Theory of Electrons* (1909), p. 52.

(2) An atom (I) thus appears in its milieu, or medium (I-a), which may contain free electrons (I-a′) and other independently arising atoms (I-a″). That atoms interact with the medium (II-a) appears from the facts of absorp-

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[29] J. J. Thomson, article "Matter," in *Encyc. Brit.* (11), Vol. 17, pp. 892-3.

[30] E. Rutherford and J. Chadwick, letter in *Nature*, 107, 41 (1921).

tion and radiation. That atoms take up and give off electrons is indicated by some of the facts of radioactivity and attendant processes; and that some atoms take up and give off other atoms (II-a″) may be inferred from the above-mentioned work of Rutherford. Such interactions involve appropriate accretions or depletions of the atoms (II-b), and, according to the theory of Bohr,[31] for example, internal and compensating interactions (II-b′)—readjustments of the constituent electrons among themselves. The accompanying chemical attractions and repulsions (II-c) vary as new interactions ensue (II-c′), for example in cases of auxiliary valencies[32] and saturation. These interactions may continue up to the point of disintegration of the atom (II-d), of which the most conspicuous known form is the expulsion of alpha-particles in radioactivity.[33] The atoms come to differ among themselves (III-a); the differences, especially apparent in atoms which make up molecules, may be summed up as differences between the terms of a duality, *i.e.,* electropositive and electronegative, or basic and acidic (III-b). This relation of duality among the atoms, considered in the order of increasing atomic numbers, is expressed by the periodic law. Atoms perhaps form aggregates (IV-a) in some of the nebulae which give line-spectra rather than band-spectra. Atoms form integrates which we call molecules, characterized by interrelations of parts (IV-b′) and differentiations of structure (IV-b″)—the chief differentiation being, again, that into central and peripheral regions. In some of the molecules, according to the octet theory,[34] the differentiation resembles that of an atom; but in the more complex molecules, at least in those of organic chemistry, the constituent atoms belong more definitely to either central or peripheral regions. Certain inorganic, rather than organic molecules are the individuated monads (I) of the next stage (3), the structures and processes of which are considered in the next paragraph. Molecules often arise not so much as the result of integrations from atoms as of differentiations within such astronomical bodies as we shall consider later; the former process is somewhat obscured by the latter (IV-c), but in either case there are interrelations of parts and differentiations of structure.

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[31] N. Bohr, letter in *Nature,* 107, 104 (1921).

[32] See A. Werner, *New Ideas on Inorganic Chemistry,* transl. Hedley (1911), pp. 35, 68.

[33] See, *e. g.,* E. Rutherford, "Radiations from Exploding Atoms, *Nature,* 95, 494 (1915).

[34] I. Langmuir, "The Arrangement of Electrons in Atoms and Molecules, *Jour. Am. Chem. Soc.,* 41 (I), 934 (1919).

(3) In order for a molecule to be an individuated monad (I) it is not necessary that the molecule should arise by a combination of atoms in "free space"; it may arise in an atomic aggregate. The assumption that molecules exist in interstellar or interplanetary space has been thought to account for the absorption of light in such regions.[35] The interactions (II) characteristic of molecular monads resemble those of the atoms. The physicist studies molecules in motion, and finds that they differ in velocities; any case of such difference presents a duality (III-b) of swifter and slower molecules. In conditions like those of a vacuum tube, velocities help to determine the results of collisions between molecules,[36] with the dislodging of atoms or ions which may form the basis of new molecules (III-b′). Molecules may be aggregated into nebulous masses, or—perhaps within these—integrated into other astronomical bodies (IV-b), which exhibit interrelations of parts (IV-b′) and differentiations of structure (IV-b″). These astronomical bodies may be minute or vast—composed of relatively few molecules, like a meteorite, or a huge assemblage, as in the case of a nebula, star, planet, or satellite; these astro-

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[35] *Cf.* the theory of "cosmic dust"—S. Arrhenius, *Worlds in the Making*, transl. Borns (1908), p. 108.

[36] *Cf.* J. J. Thomson, *Rays of Positive Electricity* (1913), pp. 52-53.

nomical bodies form the individuated monads (I) of the next stage (4). It is evident that many of these astronomical bodies must be said to arise not so much as the result of integrations of molecules, but as the result of differentiations within still larger units,[37] such as nebulae or solar systems; the former process is somewhat obscured by the latter (IV-c).

(4) Omitting much of the complicated detail concerning the structures and processes of the other astronomical bodies, let us consider briefly those of the earth, which presents a complicated case of the operation of the same general principles. According to the widely accepted planetesimal theory, the earth is one of the results of a series of disturbances produced in its parent body by a passing star.[38] The earth was at first a "planetary knot"[39] (I) in the medium (I-a) which contained free molecules, atoms and electrons, with all the interactions which we have considered (I-a′), as well as other planetesimals (I-a″).[40] The planetary knot interacted with all these (II-a, -a′, -a″), and grew by accretion[41] (II-b). At least in some knots[42] there was also depletion, for the lighter gases were radiated away. The earth's internal and compensating interactions (II-b′) include its rotation, magnetism, rock-flow, circulation of waters, atmospheric currents, stratification, weathering, volcanic eruptions, earthquakes—in short, the structures and processes studied in geology and its allied sciences. All these processes are accompanied by what is usually known as gravitational attraction (II-c), which varies according to the mass and distance (II-c′). It is conceivable that the earth's inter-

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[37] T. C. Chamberlin, *The Origin of the Earth* (1916), p. 133.

[38] T. C. Chamberlin, *Ibid.*, pp. 130, 135.

[39] *Ibid.*, p. 132.

[40] *Ibid.*, p. 141.

[41] *Ibid.*, pp. 132, 138.

[42] *Ibid.*, p. 138.

actions as outlined may lead to its disintegration (II-d), perhaps as the result of a collision with some other astronomical body, or of loss of energy and consequent falling into the sun. According to some of the older theories, the earth "threw off" its satellite (III); later theories, as noted above, are inclined to the view that such processes are found only in the parent nebula or sun, where, either with or without the agency of a passing star or other body (III-b′), a process of reproduction of one astronomical body from another or others is thought to have taken place. The individual variations between astronomical bodies tend to be obscured in the case of the earth and other planets, because of the fact that they are more or less coördinated as members of the solar system. Between stars, the individual variations (III-a) may be summed up as those between older and younger, or dwarf and giant,[43] or slower and swifter[44] stars; and we may suppose that the differences between planets[45] are remotely comparable to these. A clear case of integration (IV-b) of astronomical bodies into solar systems would require that central bodies "capture"[46] their satellites, spacing them out in such a way as to result in interrelations of parts (IV-b′), and differentiations of structure (IV-b″)—the chief differentiation, again, being that between central and peripheral portions. It is more in accord with accepted theories to say that solar systems arise not so much as the result of integrations of astronomical bodies, but as the result of differentiations within a vast parent nebula. The fact may be that both processes are in operation, with the former somewhat obscured by the latter (IV-c).

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[43] H. N. Russell, "Relations Between the Spectra and Other Characteristics of the Stars, *Nature*, 93, 253, 283 (1914).

[44] *Cf. Ibid.*, p. 286.

[45] See T. C. Chamberlin, *op. cit.*, p. 141.

[46] A. C. D. Crommelin has criticized the capture theory in *Scientia*, 17, 1 ff. (1915).

For (5) solar systems, and (6...) larger units such as clusters, galaxies, spiral nebulae, etc., the formula appears to fit so far as researches have been made; but the small amount of available data, and the possibility of varying interpretations make definite statements difficult. It may be noted that the physical and astronomical effects[47] which are now regarded as tending to confirm the Einstein theories may be taken as instances of internal and compensating interactions (II-b) within the solar system, or within one or another of the larger units—perhaps within the finite universe itself as the largest and the all-inclusive monad.

(..7 ?—11 ?..) That a formula providing for individuations, interactions with accretions and depletions, disintegrations, reproductions, integrations and differentiations of structure would apply in general to the biological monads is evident, although the manifold details of these applications require more attention than can be given them in this paper. One should note the importance, throughout the biological series, of the milieu (I-a), which now includes not merely the medium which serves as milieu for the stages preceding the biological, but also includes all those stages, and constitutes the 'inorganic environment." Each biological monad interacts with the inorganic environment (II-a), and with the biological monads of stages previously developed (II-a′), and with other monads of the same stage (II-a″); when these are reviewed in detail any given organism is described in its vital relations with the environment, other species, and other individuals of its own species. In the higher organisms the processes involved in internal and compensating interactions (II-b′), *e.g.*, periodicities of food-taking, breathing, rest, etc.; alternations of heightened and depressed vitality; growth; digestive, assimilative, circulatory, excretory and muscular systems—in short, the processes studied in physiology—present detailed complications of some difficulty. The terms "attraction" and "repulsion" (II-c) may be applied at least to the chemical processes in positive and negative tropisms;[48] it must be expected that some questions will be raised if these terms are extended to include the physiological conditions of appetite, etc., which accompany the appropriation or rejection of food, although such an extension is in line with mechanistic conceptions. Individual variations (III-a) may be summed up as differences between the terms of various dualities (III-b)—older and younger, active and inactive, well-nourished and poorly-nourished—all associated with differences of katabolism and anabolism which, according to a famous theory,[49] is the chief factor in the differentiation of sex (III-b′) in (10?) multicellular organisms. The aggregation (IV-a) or integration (IV-b) of individuals may give rise to (11 ?) social groups, marked by interrelations of parts (IV-b′) and differentiations of social structure (IV-b″). Groups contain both plants and animals. Among the animal members, a differentiation almost universal is that between leaders and followers. Sometimes social groups seem to arise not by integration of individuals—which suggests the old contract theory of society—but by differentiations within a larger and more indefinite group. The fact is that both processes are in operation, and that the former is obscured by the latter (IV-c). The inclusion of (11 ?..) social groups within the biological series means, as was indicated, a certain amount of recognition of the organismic theory of society, which is commonly held to have been discredited.[50] The point here, however, is not whether a social group is an organism, but whether a social group is a monad; and it can hardly be doubted that social groups do exhibit the various processes indicated in the monadic formula. The trouble with the organismic theory of society was not so much in the facts which it cited, even though it was guilty of extravagances; the chief trouble was in the facts that it did not cite. It left little room for the individual personality, and failed to take account of the immensely important psychological factors which everyone must recognize as operative. In short, the organismic theory was an abstraction. Let us not forget that the monadic formula is also an abstraction; all that is here contended is that the monadic formula offers the kind of abstraction with which the organismic theory agrees, and in connection with which the organismic theory can be estimated on the basis of the qualified and partial truth which it contains. Larger societies are often differentiated (IV-b″) into what may be called conservative and progressive groups, although these terms usually imply the intervention of developed values and ideas.

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[47] For a discussion of the evidence see W. H. Pickering, "The Einstein Theories," *Scientific American Monthly*, 3, 292 ff. (1921).

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[48] See J. Loeb, *The Dynamics of Living Matter* (1906), p. 138 f.

[49] P. Geddes and J. A. Thomson, *The Evolution of Sex* (1914), Chap. X.

[50] For a criticism of the theory see F. W. Coker, *op. cit.*

There are several reasons why it is not very apparent that the monadic formula applies in neurology and psychology. The first of these reasons is that the grounds for the distinction between neurology and psychology are often mistaken. The distinction, for us, is not that between the two members of a psycho-physical parallelism, nor between the two factors of an "interaction," but between a series of structures and a series of processes, essentially inseparable, for both of which the monadic formula aims to make provision. That which, from the point of view of integrations (IV-b) and differentiations (IV-b″) of the monads of any stage n, is a structure, is from the point of view of interactions (II), especially internal and compensating interactions (II-b′), of the monads of stage $(n+1)$ a process. In other words, individuation is a matter of process as well as of structure. "Neurology" is a term which covers a series of structures; "psychology" is a term which covers a series of processes—and the two are essentially inseparable. From this point of view, the distinction sometimes made between structural and functional psychology[51] might well be modified. Since neurology and psychology are for us essentially inseparable, we adopt the term "neuropsychology." The second reason for confusion with regard to the application of the monadic formula is allied with the foregoing; it is our heritage from the long debate about epistemology. According to the monadic formula, the whole epistemological problem may be considered as a special case of interaction of monads of any given stage with monads developed at previous stages (II-a′) or at the same stage (II-a″) of evolution. In general, the process of interaction (II) is cumulative from stage to stage and from series to series. When the monads which interact belong to the series numbered from (1) to (6 ?. .), the interactions are confined, as we saw, to various physical, chemical, or astronomical accretions and depletions. The monads which belong to the series numbered from (. .7 ?) to (11 ?. .) are never out of interaction with the foregoing series—biological organisms are acted upon, for example, by radiant energies, masses of matter, gravitational forces, just as if the organisms were part and parcel of the infra-organic world. But the organisms exhibit, in addition, more complicated structures and processes of their own, for example in the ingestion and assimilation of food and the excretion of waste. The fact that these biological processes are more complicated does not mean, however, that they are out of place in the world, or cannot be accounted for in the regular course of evolution. Once more, the monads which belong to the series numbered from (..12 ?) to (16 ?..) are never out of interaction with the monads of either of the two series preceding—nerve substance exhibits physiological, as well as chemical and physical interactions. But, again, nerve substance also exhibits, in addition, more complicated structures and processes of its own, which many writers, abstracting processes from structures, are content to call psychological, or psychical, and make very formidable under such names as consciousness, experience, and knowledge. But, according to the view here put forward, our experience and knowledge of the world is to be regarded as a comparatively recent and very highly complicated case of certain interactions found throughout the whole course of evolution. The fact that our sense-organs, nervous systems and muscles interact characteristically with the environment might be expected from the fact that all monads developed in the course of evolution tend to interact with monads previously developed. The "epistemological problem" is not one which has anything to do with the possibility of knowledge, for the phrase "possibility of knowledge" contains a fundamental contradiction in terms. The problem of epistemology has to do with a series of structures and processes which should be treated as descriptively as those met with in the problem of digestion. "Knowledge is natural." A third reason for confusion with regard to the application of the monadic formula to neuropsychology is that the processes of biological reproduction, especially of embryology, exercise important effects upon the development of nervous systems in all the higher species. For one thing, the course of development of nervous structures must be studied where they can be found, scattered throughout a myriad of individual organisms of different species, and subject to all manner of local conditions. Again, in the case of any one individual, the nervous system develops in the embryo by a process of differentiation which, even more than in other cases noted, obscures (IV-c) the process of integration. But we hold that these facts do not rob the monadic formula of its significance for neuropsychology; it is recognized throughout our argument that the monadic formula is an abstraction, and does not account for all the relations which we find in the actual, concrete world. Some of these relations, as we shall see later, appear not in conection with the monadic formula but with the other two implications of our principle of epitomization; and with these the facts of neuropsychology acquire a new significance. A fourth reason for confusion seems most formidable of all; it might be called the argument from the egocentric advantage—*i.e.,* that we feel, or experience, or know ourselves to be essentially different from the world about us, the world which we analyze and construct into monadic or other formulas. As a corollary of this we find the view that the fact that we have values, purposes, and ideals sets our personalities apart from the structures and processes of the world around us. This fourth point can best be treated a little later, after we have examined some of the monads of the neuropsychological series in accordance with the formula.

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[51] *Cf.* G. A. Coe, *The Psychology of Religion* (1916), p. 17; E. S. Ames, *The Psychology of Religious Experience* (1910), pp. 18, 19.

(..12?..) The first members of the new series are hardly distinguishable from those of the series preceding; they are (I) the cells which, lying usually on the outer surface of an animal's body, become highly specialized, or sensitive to specific stimuli.[52] They appear in the midst of a milieu (I-a), which at this stage of evolution has come to include the "medium" of the physical and astronomical monads, the "inorganic environment" of the biological monads, and the *"milieu interne,"* or internal medium[53] of the organism. There may also be other independently arising sensitive cells (I-a″). Sensitive cells interact with this milieu

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[52] Ladd and Woodworth, *op. cit.*, p. 16.

[53] Sherrington, *op cit.*, p. 4.

(II-a) and its monads previously developed (II-a′), and also, indirectly, in the absence of nervous conduction, with other sensitive cells (II-a″). That each interaction of these cells involves accretion or depletion (II-b), internal and compensating interactions (II-b′), attractions and repulsions (II-c) and their variations (II-c′) follows from general considerations of cell chemistry, which are not altered by the fact that the interactions of these specialized cells are specific. Sensitive cells may proliferate (III) during the growth of the organism or the regeneration of lost parts. They come, especially after the appearance of nerve cells, to be distinguished as (III-b) receptors and effectors; and perhaps, in the lower animals, the development of the latter keeps rather ahead of that of the former[54] (III-b′). Sensitive cells may be aggregated (IV-a) into sensitive areas which develop at various parts of the organism; or they may be integrated (IV-b) with one or more[55] nerve cells into what may, for the lack of a better term, be called "nervous areas." The process of integration is obscured (IV-c), if not supplanted—especially in the embryos of higher organisms[56]—by a differentiation among the cells already present. In any case, the nervous areas exhibit interrelations of parts (IV-b′)—marked by the appearance of fibrils[57]—and differentiations of structure (IV-b″). The chief differentiation is that into central (conducting) and peripheral (receptor and effector) regions. These nervous areas form the individuated monads (I) of the next stage (13 ?).

(13 ?) According to most authorities the nerve-cell or neuron, rather than its fibrils, is the fundamental unit of the nervous system.[58] It is not quite accurate, however, to

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[54] Ladd and Woodworth, *op. cit.*, pp. 16-17.

[55] *Ibid.*, pp. 17 ff. *Cf.* Sherrington, op. cit., p. 309, and note [62] on following page.

[56] *Cf.* Ladd and Woodworth, *op. cit.*, pp. 38, ff.

[57] *Ibid.*, pp. 18, 40-41.

[58] *Ibid.*, pp. 113-114.

consider the nerve-cell by itself as an individuated monad; for, from the coelenterates[59] to the human embryo[60] the nerve cells appear only between or in the midst of other cells with which they function.[61] Accordingly, we take as the individuated monad (I), the "nervous area"—one or more nerve-cells with appropriate receptors and effectors. Such a nervous area, in which there is only one nerve-cell, is sometimes called an "arc," although it is important to note that the use of the term arc varies.[62] Nervous areas containing more than one nerve-cell are found when any part[63] of the nerve-net of a coelenterate, for example, is activated; but individuality is a matter of process as well as of structure, and the term nervous area should not be applied to the whole nerve-net except when this functions as a whole. The essential mark of the nervous area, as distinguished from later individuated monads, is that its conduction is indiscriminate and reversible.[64] Such nervous areas (I) arise in the midst of a milieu (I-a)—*i.e.*, they appear in the internal medium of the organism, which is in the midst of the environment, which, in turn, is in the physical and astronomical medium. Since the nervous areas are groups of cells, including sensitive cells, they may be expected to exhibit interactions (II) which are in general like those of any group of cells; especially important are their interactions with the milieu (II-a). That these interactions are accompanied by depletion, if not accretion (II-b) may be inferred from the fact that nerves under stimulation give off carbon dioxide.[65] The internal and compensating interactions (II-b′) of these nervous areas constitute the process of nervous conduction, which, as we noted, is at this stage indiscriminate and reversible; it is also found that the action of a nerve-net does not differ essentially from that of one of its constituent parts, experimentally isolated.[66] At least in so far as the interactions of these nervous areas are chemical they may be said to involve attractions and repulsions (II-c); variations (II-c′) are apparent, for example in fatigue. The most general difference between nervous areas would appear to be that between the directions of their action, according as these are (III-b) inward or outward—the prototype of the differentiation into sensory and motor. Nervous areas may possibly form aggregates (IV-a) in organisms possessing "diffuse systems";[67] they may possibly be integrated (IV-b) in organisms which, as in flatworms and mollusks,[68] exhibit the beginnings of centralized nervous activity—but in all these cases one must keep in mind that differentiation (IV-c) is more apparent than integration. At any rate, when one compares annelids, arthropods, and vertebrates, there is evidently an increasing tendency for the nerve-cells not to anastosmose as readily as in the nervous areas; in the later species the fibres often run side by side in bundles called nerves, but each maintains its individuality; and the fibrils, at least in vertebrates, apparently do not connect the cells as in a primitive nerve-net, but end in proximity to neighboring cells—there is contiguity rather than continuity. But, in spite of all this, the annelids, arthropods and vertebrates exhibit a type of nervous conduction which is less and less diffuse and indiscriminate than that of the coelenterates with their nerve-nets, or that of the flatworms and mollusks with their partially modified nests.[69] Judging from the definiteness of the

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[59] *Ibid.*, pp. 17-18.

[60] *Ibid.*, pp. 38-41.

[61] *Cf.* Sherrington, *op. cit.*, p. 7.

[62] Sherrington (*ibid.*, p. 309) speaks of a case where "the conductor mediating between receptor and effector is itself *a separate cell* intercalated between a receptive cell and an effector cell" as "the simplest *arc* in the organisms which possss a true nervous system." But (*ibid.*, p. 7) he says "the conductor consists, in the reactions which we have to study, of at least *two* nerve-cells,—one connected with the receptor, the other with the effector." (Italics ours.)

[63] Ladd and Woodworth, *op. cit.*, p. 19, first complete paragraph.

[64] *Ibid.*, pp. 19-20; *cf.* Sherrington, *op. cit.*, p. 14.

[65] S. Tashiro, *A Chemical Sign of Life* (1917).

[66] Ladd and Woodworth, *op. cit.*, pp. 18-19.
[67] Sherrington, *op. cit.*, p. 311.
[68] Ladd and Woodworth, *op. cit.*, p. 20.
[69] Ladd and Woodworth, *op. cit.*, pp. 20-22.

process, one would say that in the more highly centralized systems a new type of individuated unit must appear—a type which structurally is in general distinguishable from the fact that it possesses two or more nervous cells whose fibres often run in bundles and whose fibrils sometimes do not unite but form connections across near boundaries. These are essential points in the structure of a reflex-arc,[70] when the term is used in the sense indicated above. Possibly, then, reflex-arcs are sometimes the products of the integration (IV-b) of nervous areas—the fact that nerve fibres so often run in bundles may indicate that each nerve-cell tends at least to maintain its primitive connections with motor and sensory cells or groups of cells, and that nervous areas are still partially traceable in reflex-arcs, although central nerve cells have now been substituted for either effector- or receptor-cells, so that, instead of running directly from receptor through conductor to effector, the impulses now run from receptor through conductor to a central nerve-cell, then from this or some other central nerve-cell to a conductor, and then to an effector.[71] One might perhaps say that central cells serve as effectors for one type of nervous area, *i.e.,* the sensory, and also as receptors for another type, *i.e.,* the motor; something like this seems traceable in certain deliberate combinations of responses with stimuli. But in the formation of reflex-arcs, processes of differentiation within the whole nervous system obscure (IV-c), if they do not supplant, such processes of integration. In any case, reflex arcs exhibit inter-relations of parts (IV-b)—evident, for example, in the synopses[72]—and differentiations of structure (IV-b′). The chief differentiation, again, is that into central, or coördinating, and peripheral, or receptor-, effector- and conducting cells. It is customary in dealing with them to speak in terms of process rather than of structure, and use the term "reflex." Reflexes serve to coördinate the activities of the organism, and also are themselves sometimes coördinated. The first grade of coördination is exhibited by the simple reflex, which we take as the individuated monad (I) of the next stage (14 ?).

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[70] *Cf.* Sherrington, *op. cit.,* pp. 15, ff.

[71] *Cf.* Ladd and Woodworth, *op. cit.,* p. 21.

[72] Sherrington, *op. cit.,* pp. 16-18.

(14 ?) The simple reflex is, according to Sherrington, "probably a purely abstract conception;"[73] Ladd and Woodworth suggest that a better term would be "isolated reflex," and that the essential point is not that the movement evoked shall be free from complexity, but that it shall run its course uncomplicated by other reactions occurring at the same time[74]—but they agree with Sherrington that probably no part of the nervous system is capable of reaction without affecting and being affected by various other parts.[75] The monadic formula is quite in accord with this, for it considers the simple reflex as possessing only a relative individuation (I) in the midst of the environment and the organism (I-a), and also whatever other reflexes may be operating within a nervous system in relative independence (I-a″). The interactions (II) of such reflexes do not differ in principle from those indicated in the case of nervous areas, although reflex conduction is usually irreversible and has other peculiarities.[76] Reflexes evidently interact with other reflexes (II-a″) in processes of "reinforcement"[77] and "spread."[78] The process of conduction itself may be regarded as an internal and compensating reaction (II-b′) within the reflex—for, whatever be the intimate nature of the process of conduction, some sort

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[73] *Ibid.*, p. 8.

[74] Ladd and Woodworth, *op. cit.*, pp. 146-147.

[75] Sherrington, *op. cit.*, pp. 8, 114-115.

[76] *Ibid.*, p. 14.

[77] *Cf. Ibid.*, p. 175.

[78] Ladd and Woodworth, *op. cit.*, p. 169,

of commotion[79] is evidently relayed from one portion of the structure to another. Interactions may continue up to the point of discharge (II-d) of the reflex; discharge does not mean the disintegration of the substance of the nerve-cells, beyond the possibility of their incorporation in succeeding reflexes, but means that the process of coördination is completed, so that energy from the receptors is at length released into the effectors, and also that the nerve-cells which have figured in the transmission are now available for incorporation into new reflexes, through the breaking up of old synaptic connections and the establishment of new connections. This latter feature is evident in the "principle of the common path."[80] Perhaps one reflex may help to give rise to or determine the course of another (III) through certain residual effects, like the lowering of a threshold[81] in a portion of its arcs. Variations between reflexes may be summed up (III-b) in any of the terms which serve to describe antagonistic reflexes[82] and those involved in processes of inhibition;[83] for one of the fundamental characteristics of nervous conduction is that one reflex is functioning in more or less opposition to other reflexes. Several simple reflexes may constitute aggregates (IV-a) juxtaposed in space, or succeeding one another in time; or, they may constitute integrates (IV-b), characterized by interrelations of parts (IV-b′) and differentiations of structure (IV-b″). It is necessary here to make some distinctions. The general term covering both aggregation and integration of reflexes, as well as interactions (I-a″) of the reinforcing or spreading type, is "combination of reflexes," and the resultant reflexes are sometimes called "compound reflexes."[84] The distinctions are, indeed, only relative; but this is also the case in connection with the other monads. We should say then that when a reflex spreads, but the result remains recognizable as merely a modified form of the original reflex, we have a case of interaction (II-a″, above). When reflexes exhibit simultaneous or successive combination, in which the constituent reflexes remain well-defined, we have a case of aggregation (IV-a). When there is a combination in which none of the constituent reflexes are so well defined, but are rather fused in a larger unified reaction, we have an integration (IV-b). To these integrates we shall apply the term "complex reflexes"[85]—they are the individuated monads (I) of the next stage (15 ?). As in other cases, we must keep in mind that they may develop within the nervous system by differentiation (IV-c) more conspicuously than by integration; but in any case they are marked by interrelations of parts and differentiations of structure. The chief differentiations are, again, into central portions—especially the various tracts and regions of the brain, which become more complex as higher species develop—and peripheral portions—the increasingly complex mechanisms of receptors, effectors, and afferent and efferent nerves.

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[79] *Ibid.*, p. 281.

[80] Sherrington, *op. cit.*, pp. 115 ff. 144.

[81] *Cf. Ibid.*, p. 184.

[82] *Ibid.*, pp. 135 ff.

[83] *Ibid.*, pp. 83, ff.

[84] *Ibid.*, Lectures V and VI, titles.

(15 ?) The complex reflex, in the general outline of its structures and processes resembles the simple reflex—so much, in fact, that we tend to describe our complex reflexes by over-simplifying them. Reflection shows that almost any act of one of the higher organisms, especially of man, involves coördination of a variety of nervous impulses coming from many different receptors and proceeding toward many different effectors. The complex reflex (I) has the same general relation to environment and organism (I-a), to previously developed nervous areas, *e.g.*, a local "diffuse system,"[86] (I-a′), and to other reflexes

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[85] Sherrington uses this term on p. 143.

[86] *Ibid.*, p. 312.

(I-a″), as is found in the simple reflexes. That a complex reflex interacts with the organism (II-a) appears from various facts in connection with emotions;[87]; that it interacts with local diffuse systems (II-a′), from the innervation of viscera, heart, and blood-vessels; that it interacts with other reflexes (II-a″), from the differences between perception and sensation.[88] Perhaps some instances of "compensatory reflexes"[89] may be regarded as internal and compensating interactions (II-b′) within complex reflexes. The terms attraction and repulsion (II-c) are not often applied to the operation of these reflexes, although such an application would be justified in connection with electro-chemical theories of nervous action. Variations in intensity (II-c′) play a prominent part in the reactions.[90] The discharge and subsequent breaking up (II-d) of a complex reflex does not differ in principle from that of a simple reflex. One reflex may help to give rise to another (III) through "association by similarity"—a small surviving portion may surround itself with new associates.[91] Differences between complex reflexes may be summed up (III-b) in any of the terms used to indicate antagonistic or inhibitory reflexes; a duality practically always found is that between tonic, or postural reflexes and clonic reflexes, or those which introduce a sharper and more definite reaction.[92] This distinction is allied with the distinction between familiar and new elements of experience, important (III-b′) in all cases of association. Several complex reflexes may by aggregation (IV-a)—mere juxtaposition in space or time—form habitual or instinctive complexes;[93] or, by integration (IV-b) form complexes which exhibit more marked interrelations of parts (IV-b′) and differentiations of structure (IV-b″). To this class of complexes belong the more highly developed instincts and emotions,[94] and, in man, the sentiments,[95] values, and "selves;" these probably represent more than one stage of evolution. Such complexes may develop by differentiation (IV-c) within the organism and nervous system, as well as by integration. The chief differentiations within a complex are perhaps those between interoceptive and proprioceptive components,[96] on the one hand—including the structures of the "sympathetic system"—and, on the other hand, the exteroceptive components, proceeding from the environment, particularly through the distance receptors. In complexes involving the action of distance receptors a prominent differentiation is that into "consummatory reactions" and "precurrent reactions;"[97] this differentiation probably furnishes a prototype of consciously purposive action—the object seen, for example, at a distance, having the function later exercised by a perceived or conceived "end," and the precurrent reactions having the functions later exercised by the various means to an end.[98] According to this view, purpose is a case of organicity; according to the traditional view, organicity is a case of purpose.

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[87] Ladd and Woodworth, *op. cit.*, pp. 523-524.

[88] *Cf.* William James, *Principles of Psychology* (1890), Vol. II, p. 3.

[89] *Cf.* Sherrington, *op. cit.*, p. 203.

[90] *Ibid.*, p. 231.

[91] James, *op. cit.*, Vol. I, p. 578.

[92] *Cf. Sherrington,* op. cit., pp. 231, 65.

[93] *Cf.* Ladd and Woodworth, *op. cit.*, p. 146.

(16?) The structures and processes of complexes must be considered briefly. That emotions, sentiments and values accord in general with the monadic formula is fairly evident, although their relationships are very complex. They are each distinguished more or less definitely (I) in the midst of the apperception mass (I-a′, I-a″). They interact with the environment and the organism (II-a), with single reflexes (II-a′), and with other complexes (II-a″)—the last point being evident, for example, in the incorporation of emotions into sentiments,[99] or of values into new values.[100] The various complexes are changed by the addition or elimination of certain factors (II-b), as well as by changes going on within their own organizations (II-b′). There are marked differences of intensity (II-c). Complexes may be dissolved (II-d), or may give rise by association to new complexes (III), with variations (III-a) which may be summed up in any of the terms (III-b) expressing the fact that complexes contend for possession of the motor centres. Several complexes may exhibit even higher integrations (IV-b) into the great complexes known as selves—or possibly into certain ideal unities worthy of the name of personalities.

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[94] *Cf.* W. McDougall, *Introduction to Social Psychology* (1915), p. 29.
[95] *Ibid.*, p. 125.
[96] *Cf.* Sherrington, *op. cit.*, pp. 129, ff. 317.
[97] *Ibid.*, p. 329.
[98] *Cf. Ibid.*, pp. 326, 330; also E. Rignano, "Attention," *Monist*, 22, 4 ff. (1912).

The last statement anticipates some very important points in the argument of this paper; for we have as yet treated values only in a very general way, and we have said practically nothing of language or ideas. Until these things which are so intimately involved in our actual experience are more adequately treated, the monadic formula must seem exceedingly abstract. It is our conviction, however, that these matters can be treated in accordance with the monadic formula, and that both our abstract theories and our concrete experience may profit by the treatment. This treatment may be summed up in six propositions, as below. The first three propositions I have treated in some detail elsewhere,[101] and hence shall merely state here.

1. Language, in the form of cries, arises among the individuals of an animal group as a result of conflicts of tendencies within their complexes. 2. Language develops sounds corresponding to the various parts of speech, and employed in articulated sentences, in proportion as the

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[99] Shand, *op. cit.*, p. 62.

[100] *Cf.* Coe, *op. cit.*, p. 222.

[101] In Section I of an article entitled "The Implicit Duality of Thinking," which will soon appear in the *Journal of Philosophy*.

actions indicated grow more elaborate, and in proportion as speakers and listeners are more and more separated from the objects and actions indicated. 3. Language reactions are, according to some theories, the essential factor in thinking; but other theories trace thinking to perceptual images, or to conflicts of motor tendencies. In any case, thinking develops by the aid of processes of abstraction, generalization, and the metaphorical use of terms.

4. The fourth proposition is that an idea is essentially a complex reflex. To call an idea a simple reflex would be to espouse one or another of the theories mentioned in 3, above, or each of them separately; but to call an idea a complex reflex does justice to the fact that an idea apparently draws both form and content from language reactions, from perceptions, and from motor tendencies all at the same time. Moreover, an idea, like any complex reflex, follows the monadic formula. In a later paper I shall try to indicate in detail that an idea, in its characteristic formulation as a logical judgment exhibits a relative individuation (I), which in logic is called identity; that a typical case of interactions (II) is afforded by predication; that a process of accretion and depletion (II-b) can be traced in affirmation and negation, respectively; that the general process of reproduction (III) appears at this stage in the process of logical inference, especially in the syllogism with its conclusion formed from the interaction of two reflexes, one of which contains somewhat familiar, and the other of which contains somewhat new elements (III-b′)—in other words, the interaction of universal and particular premises; and that judgments, together with other elements of experience, may be integrated into values (IV-b), or that values may appear as differentiations (IV-c) within a more inclusive and indefinite apperception mass. In other words, one may, I think, profitably go

farther than Bosanquet[102] and some other logicians go in the direction of a "biologizing" of logic. I hope at some future time also to develop the view that the monadic formula can be applied to some at least of the fundamental concepts of mathematics. If all this is true, it indicates that the monadic formula exhibits the structure and processes of thinking. At this point one must beware of subjectivism; for it may be said that the monadic formula is an *a priori* affair, and reflects the thinking process only, and that its use to describe the objective world is an unjustifiable projection. There is, indeed, no answer to this charge beyond that afforded by the general outcome of the idealistic as contrasted with the realistic views; but there may be a way of using the monadic formula not merely to describe the world and the thinking process, but also to conserve some of the finest features of idealism. This brings us to the objection noted above and then postponed —to the effect that we feel ourselves to be different from the world around us. Before considering it let us note briefly the fifth proposition, which will help to lead up to our answer.

5. This proposition is to the effect that language and ideas transform emotional and instinctive complexes into sentiments and values. This transformation is effected in part by language, when the consummatory and precurrent reactions are rendered communicable, and hence more definite, and when social agencies, always active where there is language, make for the recognition of common standards. At the same time thinking renders the consummatory and precurrent reactions more abstract, more general, and more metaphorical, until values tend to be dominated not merely by ideas, but also by ideals.

6. But, in spite of all this description, we undoubtedly

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[102] B. Bosanquet, *Logic, or the Morphology of Knowledge* (1888), Vol. I, p. vii.

do "feel ourselves to be different" from the world around us. How can this feeling be reconciled with the monadic formula? The answer is that precisely such a feeling is to be expected, on the basis of the monadic formula. According to the argument of this paper, the course of evolution has, as one of its notable results, the production of human social values. This production has resulted in part from what we have called (IV-b) a series of integrations. In proportion as these integrations have been different from mere aggregations, they have constituted what Professor Spaulding calls creative syntheses.[103] In them, in every case, *old things have united to form new things.* The fact that this proposition often seems impossible is due to two errors; first, the failure to recognize that, if indeed anywhere a whole can properly be said to be equivalent to the sum of its parts, it is only in the abstractions of mathematics, and especially in the number theory. In all other situations, if not in mathematics, a whole *is more than* the sum of its parts. The second error is the failure to see in the notion of newness the implicit relativity without which the notion is simply impossible. There is no such thing as the absolutely new; things that are called new have to be related to former experiences in order to be called anything at all. That old things, under appropriate conditions, unite to form new things is then the very spring of evolution—it is this process which enables the world to get from one stage of evolution to another. At early stages the atoms, molecules, astronomical bodies, etc., constitute successively the new monads. There follows a series in which the cells or the metazoa, for example, are new—they are, we may suppose, made up of monads previously developed, or they contain parts which correspond more or less closely to such monads; and they remain constantly in interaction with all preceding monads.

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[103] *Op. cit.*, pp. 448, 500.

Later on, the neuropsychological monads are new, within the meaning of the term; even if the processes of integration are obscured or supplanted (IV-c) by those of differentiation, the processes of differentiation, no less, involve combinations essentially new. At length the cumulative series issues in the development of new complex reflexes and new complexes; and these develop, as we indicated, into sentiments and values. The fact, then, that we feel ourselves different from the world in the midst of which we develop is the very expression of our essential "newness." According to the monadic formula, new monads, new stages, new series, have been appearing throughout the majestic course of evolution. When at length the stage of sustained human values is reached, *we are the new things.*

IV.

Such a monadism, even when reinforced by the important considerations just mentioned, does not completely describe the concrete world. From some points of view it is hardly more than a first approximation to such a description; for it is almost inextricably involved in the detail of structures and processes, and lacks the perspective essential to a more adequate philosophy. But within the monadistic arrangement as outlined there is already implicit what we take to be the second implication of the hypothesis of epitomization. According to this view, there is something more than convenience involved in the fact that the descriptive sciences seem to fall so easily into what may be called cosmogonic, biological, and neuropsychological groups. A consideration of these groups, from the point of view at which we actually find ourselves within them, indicates the following points: 1. The chief gaps in our knowledge occur between the groups as noted, or just outside them. 2. Cosmogonic monads are, in general earlier to appear than biological, and biological monads are earlier to appear than neuropsychological. 3. Of striking interest is it that at a certain stage, (4), in cosmogonic evolution, as noted (*i.e.,* in one of the planetary members of a solar system—the earth), when o nemight expect the course of cosmogonic evolution as thus far indicated to proceed to further integrations of higher astronomical monads, such as (5), (6), etc., some of the complex molecules within the planet set up a new series of stages, the biological, which, when compared with the cosmogonic series, may be described as a kind of internal deployment. Again, later, at a certain stage (10?) in biological evolution, as noted (*i.e.,* in some of the multicellular animal organisms which are in a group including plants), when one might expect the course of biological evolution as thus far indicated to proceed to further integrations of biological monads, such as (11?), etc., some of the complex cells within the organisms set up a new series of stages, the neuropsychological, which, compared with the biological series, may be described, again, as a kind of internal deployment. This striking similarity is not lost if one thinks of the solar system (5) and the earth (4) as arising through processes of differentiation within a larger aggregate, the primitive nebula (IV-c)—for one may also think of social groups (11?) and multicellular organisms (10?) as arising by processess of differentiation within a larger aggregate of primitive protoplasmic forms (IV-c). Taken altogether, there seems to be a point here which deserves more attention than it has received. 4. Of the nomads which most intimately concern us, the earth is much larger than any multicellular organism or social group; and any multicellular organism is much larger than any complex reflex or sentiment- or value-complex. 5. Once more, of these monads which most intimately concern us, the earth contains the multicellular organisms and social groups—we do not live on the earth, but in it, beneath its atmosphere; and, again, the multicellular organisms contain the complex reflexes and the sentiment- and value-complexes. 6. Finally, the earth, although more ponderous in its processes, is less delicately adjusted and intricate than the multicellular organisms are in theirs; and the organisms, although more ponderous in their processes, are less delicately adjusted and intricate than the complex reflexes are in theirs.

The monadic formula, exhibiting essential similarities of structures and processes, enables us to observe parallels between any or all of the monads noted. The relations just indicated between the cosmogonic, biological, and neuropsychological series suggest that a parallelism drawn between the structures and processes of the three series as such may be of special significance. Such a parallelism, shown below, leads to the formulation of the second of the three implications of the hypothesis of epitomization, as follows: Essential similarities of structures and processes are repeated, not only in monadic stages, but in the cosmogonic, biological, and neuropsychological series as such, with successive relations of container and contained; on smaller scales; but with higher degrees of complexity—or, as it may be put briefly, *cosmogony is epitomized by biology; biology, in turn, is epitomized by neuropsychology.*

Such a parallelism would exhibit the monads and series thus:

Cosmogonic (Medium)	Biological (Environment)	Neuropsychological (Internal Medium)
(1) Electrons	(..7 ?..) Organic Compounds	(..12 ?..) Specialized Cells
(2) Atoms	(8 ?) Chromatin (?)	(13 ?) Nervous Areas
(3) Molecules	(9 ?) Unicellular Organisms	(14 ?) Simple Reflexes
(4) Astronomical Bodies	(10 ?) Multicellular Organisms	(15 ?) Complex Reflexes
(5) Solar Systems	(11 ?..) Social Groups	(16? ..) Complexes
(6 ?..) Clusters, Galaxies, etc.		

The full development of this principle of epitomization in accordance with the parallelism would require all the details mentioned in Section III of this paper, and a great many more. Without attempting a detailed treatment, we may note briefly some of its significant features. In the first place, the serial numbering tentatively adopted above is carried over. The cosmogonic series is thus made to contain more monads than either of the other series, although the number of successive monads called by the term "social group" or "complex" might justifiably be increased. But there is nothing in the principle of epitomization which would require that the number of stages in each series must be equal; and there are so many questions concerning the individuation of the later monads in all three series that it is better not to attempt further extensions for the present. As new monads are discovered or distinguished in future, it is quite possible that the parallelism may need to be modified; indeed, as it now stands, it represents a line of inquiry rather than an established result—but it is a line of inquiry which offers some striking possibilities in the way of a new correlation of the sciences.

It is noticeable, in the second place, that the parallelism sets over against one another three portions of the world which in the various sciences and groups of sciences are apt to be forgotten or neglected—the "medium" in the midst of which the cosmogonic monads develop and with which they interact; the environment in the midst of which the biological monads develop and with which they interact; and the "internal medium," which sustains similar relationships to the neuropsychological monads. Without attempting to explore the detailed possibilities here, let us note that one may construct at least a rough parallelism between current theories in these three groups of sciences, according as the milieu appropriate for each group is regarded as differing in degree or in kind from the monads which it contains—as conforming, in a modified way, to the laws which are observable among the monads, or as having laws of its own, to which the monads form departures or exceptions.

The next line of the parallelism as shown above brings us to some monads which have what we may call an intermediary relationship between the milieu and the later monads in each series. Thus electrons, while different from the medium, are still not material bodies; organic compounds, while different from the environment, are not living forms; and specialized cells, while different from the internal medium, still do not have the properties of a nervous system. Yet, in each case, the monad mentioned is utterly indispensable for the structures and processes of the later monads of the series. Apparently, on the other hand, each of these monads in its interactions releases into the milieu something which is more akin to the milieu than to the later monads; the electrons set up radiations in the medium, the organic compounds split off less complex organic, or even inorganic components, into the environment, and the specialized cells probably discharge some physiologically active substance into the neighboring cells.

That atoms, chromatin, and nervous areas are set in parallel affords a suggestion which, taken in connection with what has just been said, may help to lift the reproach which has too long and too unjustly been heaped upon materialism. The atom, as contrasted with the electron, is admittedly a material body; possibly chromatin, and certainly unicellular organisms, as contrasted with organic compounds, are living forms; possibly nervous areas, and certainly some of the later neuropsychological monads are, while they function, conscious. The suggestion, which cannot here be developed in detail, is that matter, instead of being the antithesis of life and consciousness, tends to be their analogue. It is further noticeable that atoms, chromatin and nervous areas each exhibit somewhat wide variations in magnitude—the monads of each of these stages are not to be thought of as of uniform size. Atoms consist of one or more electrons and one or more positive nuclei; chromatin consists of organic compounds and nucleic acid in varying proportions;[104] nervous areas consist of one or more specialized cells and one or more nerve-cells. A question which calls for special investigation is whether there is not a significant resemblance between the interactions of atoms, with their positive and negative valencies and their valency electrons; chromatin, in its connection with dominant and recessive characters as conditioned, according to the hormone theory of heredity, by organic products split off from the chromatin of the germ-cells; and nervous areas, with their structures and processes which make possible the reinforcement or the inhibition of one reaction by another. This question involves not only these monads, but also some of the later monads of each series, and is too complex for detailed treatment here.

Concerning molecules, unicellular organisms, and simple reflexes when the last named term is understood in the sense used above, it may be remarked that each of these monads, under conditions known to us at present, is more capable of relatively independent existence than are the monads previously developed, but is less familiar to us than later monads.

The parallelism between astronomical bodies and multicellular organisms gives point to biological and physiological comparisons sometimes found, for example, in the work of Chamberlin, and to the more definite assertions of S. Meunier[105] that there are significant resemblances between geological processes and biological processes. These, again, are too complex to be discussed here; and whether the resemblances can be extended to the process of conduction as we have it in the monad of the third series, the complex reflex, must also be left open. The most significant point in connection with the threefold parallelism as indicated is the successive relation of container and contained, the importance of which was emphasized above; the monads of the biological series may be said to arise from some of the molecules within one of the astronomical bodies; and the monads of the neuropsychological series may be said to arise from some of the cells within one of the biological organisms. The parallelism is affected, although hardly vitiated, by the fact that we know for certain one astronomical body which is inhabited by biological organisms, whereas we know myriads of organisms which have nervous systems. There may be some significance in certain facts in connection with these monads which, however familiar they are when taken separately, seem strange when set side by side—that, as astronomical bodies, planets exhaust their energy before the suns on which they depend exhaust theirs; further, that, of biological organisms, the animals, in general, expend energy, while the plants upon which they depend store up energy; and finally that, of complex reflexes, the clonic reflexes run their course quickly, while the tonic reflexes are sustained for longer periods.

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[104] E. B. Wilson, *op. cit.*, pp. 240-242.

[105] *Les Harmonies de L'Evolution Terrestre* (1908); *La Geologie Biologique* (1914).

We have already noted that the parallelism between solar systems and other astronomical groups; social groups of various kinds; and complexes of various kinds, is not worked out in detail. It is only recently that the individuation of some of these monads has been recognized, and the fact that they transcend our ordinary relationships and ways of thinking renders them very difficult to treat. Possibly, when it comes to be recognized that a social group may function in super-individual ways, there may be recognized also some analogous doctrine to the effect that a sentiment- or value-complex may function in super-ideational or super-rational ways, which may still be valid. At this point the argument for epitomization might establish contact with intuitionism and mysticism.

A few words may be added concerning the relationships of the three series when each is taken as a whole. In the first place, when the details are worked out, it may be possible to strike totals, so to speak, for each series, and point out an epitomizing relationship between the totals—thus, it can perhaps be said, the cosmogonic universe is epitomized in the biological population of a planet; and the biological population is, in turn, epitomized by the apperception mass of an individual. But for the present this generalization is too remote.

There is a certain significance, however, even in the gaps in our knowledge; for, since the chief gaps in our knowledge occur between the series, or outside them, and since spaces between them must for the present be left open, the above parallelism is at present applicable either in a mechanistic or a vitalistic biology, and in either a behaviorist psychology or a psychology which makes of consciousness a kind of intervening agent. There is a possibility that the parallelism, taken together with the other implications of the principle of epitomization, may reinforce Professor Bergson's suggestion[106] of a line of reconciliation between some of these contending schools. Perhaps the conceptions of mechanism should be employed to describe the chemical origin of the life process, while those of vitalism should be interpreted to signify the fact that the biological series departs from the cosmogonic series in what we have called an internal deployment. In other words, perhaps mechanism is properly a concept of origins, while vitalism is properly a concept of orientations of the biological series with reference to the cosmogonic. Similarly, perhaps behaviorism can tell us more of the origins and elementary characteristics of the neuropsychological series, while the older views exhibit more of the orientations and larger relationships of the neuropsychological structures and processes. Of course, the gaps between the series may indicate that here extraneous forces intervene —that some vitalistic impulse produces the structures and processes of the biological series, and some quasi-spiritual force those of the following series. The parallelism would, if necessary, accommodate such extraneous forces; but it is more economical of one's concepts to regard the series as appearing without such interventions. The universe, according to the view here taken, might be said to be like one of the projectiles from a modern long range gun, which, after passing through a certain trajectory, produces a second explosion, and then, after passing through another trajectory, produces a third. In the case of the projectile, one does not need to assume that forces from outside intervene to produce the later explosions; one says, simply, that the projectile is built that way. Nor does one need to assume that there are such intervening forces in the case of the universe; one can say that the universe, also, is built that way—although this illustration must not be pressed to the point of eliciting from it a cosmological or a teleological argument.

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[106] *Creative Evoluton,* transl. Mitchell (1916), pp. 30-31.

V.

The second implication of epitomization, as considered above, does not yet exhibit our concrete world in all the fulness of relations which characterize its parts; the threefold parallelism of the preceding section is still in many respects an abstraction. One further step toward concreteness (although this again is not the final step) may be taken when, instead of considering the cosmogonic, biological and neuropsychological series singly, in their relations to one another, the first and second are taken together, in their essential connection, and set in parallel to the second and third, also taken together, in their essential connection. This is quite Fechnerian,[107] although the Fechnerian consequences do not necessarily follow from it. When the first and second series are taken together, we have ecology; when the second and third are taken, we have physiological psychology. The third implication of the hypothesis of epitomization is that *ecology is epitomized by physiological psychology;* the living organisms are to the earth as the nervous system is to a multicellular organism. Of course, in the concrete world of actual experience, all three exist in indispensable and very complex relationships; but it is held that this fact adds to, rather than diminishes, the significance of the abstractions indicated.

According to this third implication, taken in connection with the others, we may say that social groups in the history of the earth may be compared to complexes in the experience of an individual. An argument, too long to indicate in detail, may be worked out to the effect that the more definitely organized and established social groups—*i.e.*, the civilized human groups—are comparable to the more definitely articulated and persistent complexes—*i.e.*, the value-complexes; and that individual men within the groups, who are either leaders or followers, are comparable to ideas within the complexes, which are either "ends" or "means." The death of an organism in the earth may be compared to the discharge of a reflex in an organism; a view which recalls the essential point of one elaborated by Royce.[108] We may say that after the death of an organism portions of it are either incorporated into other organisms, or the biological processes are succeeded by processes which belong to the cosmogonic series; and, similarly, that after the discharge of a reflex portions of it are either incorporated into other reflexes, or the neuropsychological processes are succeeded by processes which belong to the biological series. The third implication of epitomization has also a bearing upon the organismic theories of society; it might be worth while to see how many of the accredited objections to these theories would be removed if society were to be thought of not as an organism, but as a kind of organ, comparable, as Herbertson[109] has suggested, to a nervous system of the earth.

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[107] See *Zend-Avesta* (1854), Vol. I, p. 286.

[108] *The World and the Individual,* Second Series (1908), pp. 317 ff.

The general result of the three implications of epitomization is a view that the structures and processes of the universe tend, by a kind of progressive concentration throughout the monads of the three series, to be, so to speak, distilled into the social groups, and, through these, into our values and ideas. This view regards the universe as not merely evolving, with the result that men and their experiences have appeared, but also as epitomizing, with the result that men and their experiences have a significant relation to the whole. At this point the hypothesis of epitomization is in general accord with the views which construe the problem of philosophy of religion as a problem which concerns man's relation to the universe; but the implications of the hypothesis for a philosophy of religion must be left for more detailed treatment. The affiliations of the hypothesis in the history of philosophy are with those fantastic but remarkably widespread and persistent theories of macrocosms and microcosms, particularly with the view that man is a microcosm, or little universe. But the views here put forward do not rest upon this historical basis. The problem of the relation of the universe and man is, for our age, first of all a scientific problem, and calls for the contributions of the great specialists along a thousand lines of inquiry. But it is no narrowly specialized problem; it calls also for correlation, for perspective, sometimes for speculation, and for all the resources of philosophy. The aim of this paper has been to raise the question, and to indicate some of the possible steps in its solution. It ought to be possible to decide on scientific grounds whether the construction which is here put upon the data of evolution is justified, and, upon philosophical grounds, whether the result is, or may sometime be worth while.

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[109] The Higher Units, *Scientia*, 14, 212 (1913).

In connection with this argument, something should be said about the use of the method of analogy. It is our conviction that much that is said against the method is conventional, and is directed against its more obvious abuses; and that, as a method, it has yet to receive its adequate evaluation. Of course it must be granted that there are many differences between the various monads and the various series; indeed, from some points of view, the differences are more important than the resemblances. But still the resemblances are there; and when the monadic formula is developed in detail, many of the differences appear as differences of complexity in later as compared with earlier stages, rather than as differences of essential processes involved. In our argument, reliance is placed not merely upon a number of analogies, although the number is quite formidable and, if one insisted upon a logical justification of the method, might serve as data for induction to a general law of analogy under which particular cases might be subsumed. Reliance is placed rather upon what we have called the essential character of the analogies. It is held that false analogies, common in reasoning, are usually hasty or superficial analogies, but that the analogies indicated in the monadic formula and in the parallelism are essential. They are essential in the sense that, so far as we can detect, the world known to us would not have developed without such structures and processes; or, to put the same thing in another way, they are essential because they constitute a system of metaphysics. And a consideration of the importance of these structures and processes ought to make for the view that the many striking analogies which the universe admittedly contains should be capitalized, and that new analogies should be looked for, and that old and new together should be developed into an instrument of real usefulness in science and philosophy.

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